MOTORS • DRIVES • GENERATORS

Comparison of IEEE 841 1994 to 2001- Where Might the Standard Go on the Next Revision Cycle?

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Abstract – This paper will discuss the changes that took place when IEEE Standard for Petroleum and Chemical Industry – Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors – Up to and Including 370 kW (500 hp) was changed from the 1994 to the 2001 revision. Ideas for the next revision cycle will be introduced for consideration.

Index Terms – Electric motor, Induction motors, TEFC motor, Severe Duty Motor, IEEE 841

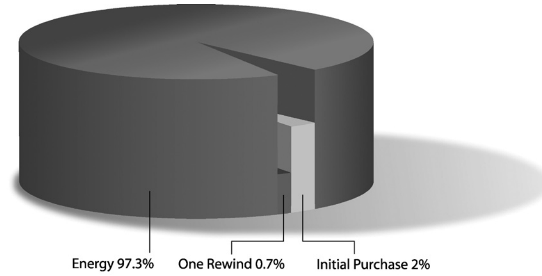

Figure 1. Motor Life Cycle Costs

I. INTRODUCTION

This paper will point out the basic differences between IEEE 841-1994 and IEEE 841-2001 revisions. The features added to the 2001 revision were intended to improve motor reliability and life. Motor efficiency was raised, but most manufacturers have exceeded this level and are supplying NEMA Premium® efficiency levels. The IEEE 841 standard is widely adopted beyond the petroleum and chemical refining industries. It is used by pulp, paper and other industries desiring an increase in manufacturing uptime.

II. LIFE CYCLE COSTS

In a process industry, motor decisions should be made on the basis of life cycle costs, not initial purchase price. Looking at life cycle costs, the cost of the motor accounts for about two percent of the motor's life cycle costs. About 97% of the life cycle costs are from energy to power the motor. This makes buying a motor with NEMA Premium® efficiency very important. [7]

III. CHANGES FROM 1994 TO 2001

Several changes were made to the standard and the more important changes are:

1) NEMA MG 1 references were updated to the 1998 edition.
2) The standard was changed to Metric units instead of English units. Dual units are not provided for easier use.
3) The motor's stator insulation system must pass a test: The stator shall be exposed for 168 h in a 40°C closed chamber, in which an open water vessel is maintained at an elevated temperature, resulting in 100% relative humidity plus condensation on stator windings. Insulation resistance at the end of the test shall not be less the 5 MW (measured with a 500 volt meg-ohmmeter at 1 minute), at or corrected to 40° C. It may be necessary to provide some variation in water and air temperature to maintain visible condensation.
4) Windings must withstand voltage spikes defined by NEMA MG 1-1998, Parts 30 and 31 allowing for use with PWM waveforms of adjustable speed drives.
5) Replaceable, corrosion resistant automatic drainage fittings must be installed in conduit boxes for voltages above 600 V or for frame sizes exceeding 445T at 600 V.
6) Motor sound tests should be conducted at rated voltage and frequency from sine wave power.
7) Minimum efficiency levels for low voltage motors 1 - 200 horsepower will be one NEMA efficiency band above EPAct.
8) Stainless steel nameplates must be stamped, embossed or etched.
9) A new IEEE 841 data sheet was created based on Process Industry Practices (PIP), Construction Industry, University of Texas - Austin, TX.

IV. CORROSION AND MOISTURE PROTECTION

To improve the motor's reliability and life, IEEE 841, 2001 requires motors to be built with cast iron frames, endplates, fan covers and conduit boxes. These 841 motors are required to perform in an environment with a higher degree of protection than standard TEFC Severe Duty motors. Cast iron parts are usually undercoated with an epoxy-based primer and finish-coat. Normally during assembly, these motors have a corrosion-resistant material between the endplate and stator frame rabbets. This standard specifies in section A.2: The manufacturer shall perform the corrosion resistance test specified in ASTM B117-97 for 96 h. At the end of 96 h, the frame paint system shall exhibit continuous adhesion, without lifting, and no visible corrosion except at high points of castings.

V. WINDING CORONA TESTING

In an effort to reduce energy consumption and improve process flow, an increasing number of pulp and paper mill motors are being operated from adjustable speed drives (ASDs). The PWM waveform from these drives often causes voltage spikes that may damage conventional motor winding insulation systems.

Over the last few years, much work has been done to improve insulation systems to withstand voltage spikes as defined by NEMA MG 1, part 31.4.4.2. Most manufacturers now use a type of magnet wire with multiple coats of specialized insulation, which reduces corona from inverter induced voltage spikes.

In addition, testing equipment, such as Hipotronics, Model # 730/10-100AMDSF, is now available from several manufacturers to measure the corona on the motor stator before the motor is assembled. This non-destructive test uncovers any defects in the magnet wire insulation (pinholes), handling damage from scratched winding or voids in the varnish after dip and bake of the stator.

VI. EFFICIENCY IMPROVEMENTS

Efficiency levels for IEEE-1994 were at the levels outlined by the Energy Policy Act of 1992 (EPAct). IEEE 841-2001 raised the EPAct levels by one NEMA efficiency band above EPAct.

When IEEE 841-1994 was being revised, the accepted "Premium Efficiency" standard being benchmarked was from the Consortium for Energy Efficiency (CEE). In August 2001, NEMA and CEE harmonized these efficiencies and introduced the NEMA Premium® efficient motor standard in NEMA MG 1, 1998 (rev 2). NEMA Premium® became the new benchmark. Since 841-2001 was released, manufacturers upgraded (or are in the process of) their 841 motors to meet or exceed the premium efficiency level.

VII. NAMEPLATE ENHANCEMENTS

IEEE 841 nameplates have always contained more data than NEMA MG 1 specifies. More users are now performing balance analysis using analyzers, which require the number of stator slots and rotor bars. The authors believe this should be a required field on the nameplate.

TABLE 1.
NAMEPLATE COMPARISONS

Nameplate Field	NEMA MG 1	IEEE 841	Proposed
Mfg type & frame designation	X	X	
Horsepower output	X	X	
Time rating (duty cycle)	X	X	
Maximum ambient temperature	X	X	
Insulation system (class)	X	X	
RPM at rated load	X	X	
Frequency	X	X	
Number of phases	X	X	
Rated-load amperes	X	X	
Voltage	X	X	
Code letter for locked-rotor kVA per horsepower	X	X	
Design letter	X	X	
NEMA nominal efficiency	X	X	
Service factor	X	X	
Service factor amps if S.F.>1.15	X	X	
Guaranteed Minimum Efficiency		X	
Motor weight		X	
AFBMA Bearing size (each end)		X	
"Complies with IEEE 841-2001"		X	
Maximum space heater surface temperature (deg C) in 40C ambient		X	
Manufacture date (Month/Year)		X	
Number of rotor bars			X
Number of stator slots			X

Per NEMA MG 1part 10.40.1, IEEE 841-2001, part 10.1

VIII. CONDUIT BOXES

Conduit box sizes have grown over the years as mandated by the National Electrical Code (NEC). The 1994 and 2001 revisions of IEEE 841 have specified a conduit box with volume twice that of the NEC.

TABLE 2.
COMPARISONS OF CONDUIT BOX VOLUME

Rated power kW	Rated power HP (460v)	Maximum Full-Load Amps	NEC / NEMA cm3 (in3)	IEEE 841-2001 cm3 (in3)
0.75 and smaller	1 and smaller		172 (10.5)	393 (24)
1.1, 1.5, 2.2	1.5, 2, 3		275 (16.8)	393 (24)
3.7, 5.5	5, 7.5		367 (22.4)	524 (32)
7.5, 11, 15, 19, 22	10, 15, 20, 25, 30	45	595 (36.4)	852 (52)
30, 37	40, 50	70	1,265 (77)	1,803 (110)
45, 55	60, 75	110	2,295 (140)	3,277 (200)
75, 95	100, 125	160	4,135 (252)	5,900 (360)
110, 150	150, 200	250	7,380 (450)	10,815 (660)
187, 225	250, 300	400	13,775 (840)	
261, 298, 336, 373	350, 400, 450, 500	600	25,255 (1540)	

Note: Authors have added cm3 metric volumes to NEMA standards and in3 volumes to IEEE standards for ease of comparison.

The conduit boxes for these three lead motors are being supplied with conduit openings larger than the conduit that enters the box, which adds cost to the installation. The threaded holes entering the conduit box should be studied during the next revision cycle.

IX. NEED FOR CLARIFICATION IN SPECIFICATION

A. Typical IEEE 841-2001 Motor Protection

In order to comply with the IP55 rating on 320-up frames, almost all manufacturers supply a rotating labyrinth seal on the output shaft of the motor. Many supply this seal on the output shaft of all sizes, making all ratings IP55 instead of IP54. Some manufacturers also supply a rotating labyrinth seal on the fan-end shaft extension (under the TEFC fan); some only provide machining to add this seal later, if desired. This inconsistency causes confusion for users. Since most users expect rotating labyrinth seals on both ends, the authors believe the seals should be specified in the standard.

B. Lead Wire Termination

Terminal lugs are also mentioned in the 841 standard as: Stator winding lead terminals, if supplied, shall be of the copper alloy seamless compression type. Again, many users expect this to be a standard feature. IEEE 841 does not specify terminal lug ring size. (Users specify different wire and lug ring sizes, which add to confusion.) In the authors' opinions, lead wire lugs should be considered for inclusion in the next specification review.

Many manufacturers are supplying motors with Class F lead wire and the lead terminals are rated for 75° C. Higher temperature, all-copper lugs should be discussed during the next review cycle.

C. Anti-Friction Bearings

Most motors stocked are supplied with deep-grove ball bearings and suited for either coupled or belted loads. The 841 standard includes motors through 500 horsepower. Frames 447, 449 and larger require roller bearings for most heavy-belted loads common in pulp and paper mills. The worksheet does not provide a place for pulley and belt data to easily verify these bearing selection requirements. This forces the users to carry two spares.

Many users also request that the bearing size on the opposite drive end be the same as the drive end bearing. Users must decide if the convenience of same size bearings outweighs many negatives. This larger bearing on the fan end of the motor is not required to handle coupled or belted axial or radial loads. The larger size ODE bearing adds friction losses to the motor resulting in lower efficiency compared to the use of a conventional smaller bearing. Some incremental cost increase is also associated with the larger fan end bearing. Nonetheless, many users are convinced that this larger bearing is supplying longer life and less spares to carry. If the users vote to favor same-size bearings, it should be added to the specification.

D. Sleeve Bearings

Some users in the petroleum and chemical refining industry are asking for IEEE 841 motors with sleeve bearings. This complicates the standard somewhat as sleeve bearings change the rotor support stiffness and may alter the critical speed of the motor. A new American Petroleum Institute (API) Standard API 547 is being developed that will cover "standard" TEFC and WPII motors 250 – 2000 HP. This new standard is being written and is an attempt to develop a standard from API 541 for less critical motor applications. Perhaps these motors may serve as sleeve bearing motors without adding this requirement to IEEE 841.

E. Lubrication

IEEE 841 currently specifies a polyurea-based grease. In an attempt to specify a motor with "lubrication for a lifetime", some user's 841 specs require sealed bearings with lithium grease. Other users are seeing longer bearing life by using synthetic greases. Maybe some of the smaller motors could be built with a synthetic greased sealed bearing. Some discussion on the relative merits for each of these ideas should occur during the next revision cycle.

F. Vibration Limits

IEEE 841-2001 specifies vibration limits well below that of NEMA. Practice has shown that even lower limits may be possible (0.04 in/sec rather then 0.08). Users should be polled to see if this is a feature that may have value to them.

G. Further Efficiency Improvements

The next logical step for the standard is to acknowledge the NEMA Premium® efficient motor level and change the standard to represent the motors actually being supplied by most manufacturers. In an ad-hoc meeting at the 2002 IEEE PCIC conference in New Orleans, the majority favored adoption of NEMA Premium® efficiency levels on the next revision.

TABLE 3
NOMINAL EFFICIENCY FOR 4-POLE TEFC MOTORS

HP	KW	EPAct IEEE 841-1994	IEEE 841-2001	NEMA Premium®
1	0.75	82.5	84.0	85.5
1.5	1.1	84.0	85.5	86.5
2	1.5	84.0	85.5	86.5
3	2.2	87.5	88.5	89.5
5	3.7	87.5	88.5	89.5
7.5	5.5	89.5	90.2	91.7
10	7.5	89.5	90.2	91.7
15	11	91.0	91.7	92.4
20	15	91.0	91.7	93.0
25	19	92.4	93.0	93.6
30	22	92.4	93.0	93.6
40	30	93.0	93.6	94.1
50	37	93.0	93.6	94.5
60	45	93.6	94.1	95.0
75	55	94.1	94.5	95.4
100	75	94.5	95.0	95.4
125	95	94.5	95.0	95.4
150	110	95.0	95.4	95.8
200	150	95.0	95.4	96.2
250	190	-	95.0	96.2
300	220	-	95.4	96.2
350	260	-	95.4	96.2
400	300	-	95.4	96.2
450	340	-	95.4	96.2
500	370	-	95.4	96.2

H. Additional Nameplate Data Fields

As mentioned previously, users are using vibration analysis equipment that requires the number of stator slots and the number of rotor bars. This data should be considered for addition to the nameplate data fields. Some manufactures include this on a separate nameplate. In addition, the no-load current should have a field on the nameplate. All nameplates on motors for the pulp and paper industry should be stainless steel with raised letters. Other types of analyzers require the stator resistance, wye or delta, for the motor. Some manufacturers include this data with the data sheet supplied with each motor. Some manufacturers include this data on a separate nameplate. For safety reasons, all nameplates should be held down with four eschuction pins.

X. IEEE STANDARDS METRIFICATION

A. Enclosures

As standards come up for revision, IEEE is suggesting metrification of each standard. In the case of IEEE 841, some items specified do not have IEC equivalents.

Many lower HP IEC motors utilize cast aluminum frames and endplates with an integral F3 conduit box. Larger motors use cast iron frames, but many still retain the cast-in F3 conduit box location. IEEE 841 specifies cast iron frames, endplates, conduit boxes and fan covers. Conduit boxes should be gasketed (half glued), diagonally split, rotatable in 90-degree increments and held down with a minimum of four bolts with conduit openings suitable for the three leads supplied by the user. Based on these present IEEE 841-2001 construction requirements, IEC motors do not comply with the construction criteria.

The level of protection specified for IEEE 841 is IP54 and IP55 for motors with frame sizes over NEMA 320. Although these are IEC designations, IEC motors utilize contact seals on the shaft to comply. Most current NEMA motors utilize non-contacting rotating labyrinth bearing isolators as expected by the users.

B. Efficiency

The efficiency standards for IEEE 841 are based on NEMA standards, with the revised specification moving to NEMA Premium® efficiencies based on testing per IEEE 112, Method B. IEC has no equivalent premium efficiency standard and the IEC 60034-2 testing does not provide equivalent results.

The European Union (EU) and Committee of European Manufacturers of Electrical Machines and power Electronics (CEMEP) have developed a motor efficiency classification scheme for motors in the range of 1.1 – 75 kW. Motors sold in Europe will have en efficiency marking designating Eff1 for their best efficiency, Eff2 for standard efficiency. There is a lower Eff3 level for a family of motors that the EU is encouraging manufacturers to discontinue. Eff1 motor efficiency is comparable to the U.S. EPAct motor. There are current discussions to set minimum regulated standards as the U.S. has done with EPAct.

The U.S. standard test for motor efficiency is IEEE Standard 112, Method B. The equivalent Canadian Standards Association (CSA) test is C390-98 and is also accepted by the U.S. Department of Energy. The IEC test standard is 60034-2. This is not an equivalent test to IEEE 112 because IEC 60034-2 and the proposed IEC 61972 tests assign specific values to stray load losses rather than measuring the losses as in IEEE tests. Table 4 shows the IEC assigned losses.

TABLE 4
IEC DEFAULT VALUES FOR STRAY LOAD LOSSES

Motor Size		Assumed stray load losses (% of full-load input power)	
HP	**kW**	**IEC 60034-2**	**IEC 61972**
1	0.75	0.50	3.00
1.5	1.1	0.50	2.99
2	1.5	0.50	2.99
3	2.2	0.50	2.98
5	3.7	0.50	2.97
7.5	5.5	0.50	2.96
10	7.5	0.50	2.94
15	11	0.50	2.92
20	15	0.50	2.89
25	19	0.50	2.86
30	22	0.50	2.84
40	30	0.50	2.78
50	37	0.50	2.72
60	45	0.50	2.66
75	55	0.50	2.58
100	75	0.50	2.44
125	93	0.50	2.30
150	112	0.50	2.16
200	150	0.50	1.88
250	187	0.50	1.60
268	200	0.50	1.50

While the IEC procedure assigns stray load losses, the JEC-37 efficiency test standard for Japan ignores stray load losses altogether. Only IEEE 112 and CSA C390-98 tests actually compare measured input and output watts giving a true measurement of the motor's actual efficiency. Test results using IEC and JEC methods cannot be directly compared with IEEE 112 or CSA C390-98 because they do not contain a measurement of all of the motor's losses. A comparison of efficiency when testing by each method is shown in Table 5.

IEEE and CSA methods accurately measures watts in and watts out that allow for segregating the motor's losses into five categories:

Iron Core Losses – Magnetic losses in laminations, inductance and eddy current losses.
Stator Resistance – Current losses in the windings
Rotor Resistance – Current Losses in the rotor bars and end rings
Windage and Friction – Mechanical drag in bearings and cooling fans
Stray Load losses – Magnetic transfer loss in the air gap between the stator and rotor

TABLE 5
APPROX. ESTIMATION OF COMPARABLE EFFICIENCY LEVELS OF SAME MOTOR USING JEC, IEC AND IEEE TEST METHODS

Motor Size		Approx. Motor Efficiency by different test methods		
HP	**kW**	**IEEE 112B / C390-98**	**IEC 34-2**	**JEC-37**
1	0.75	76.8	78.8	79.6
2	1.5	81.1	83.1	83.8
3	2.2	81.4	83.4	84.1
5	3.7	83.9	85.9	86.5
7.5	5.5	84.8	86.8	87.3
10	7.5	85.6	87.6	88.1
15	11	87.4	89.4	89.9
20	15	88.3	90.3	90.7
25	19	88.9	90.4	90.8
30	22	89.8	91.3	91.7
40	30	90.4	91.9	92.3
50	37	91.0	92.0	92.4
60	45	91.5	92.5	92.8
75	55	92.0	93.0	93.3
100	75	92.0	93.0	93.3
125	95	92.2	92.7	93.0
150	110	92.8	93.3	93.6
200	150	93.8	94.3	94.6

Source ERM 1999

C. Other Metrification Concerns

In the US, flying leads with terminal lugs are provided for connection within the conduit box. Typical IEC practices are a copper terminal strip in the conduit box.

XI. INCREASED EFFICIENCY– REDUCE DOWNTIME

Industries other than Petroleum and Chemical users are specifying the IEEE 841 motors because of their electrical qualities including an efficiency, which meets or exceeds the NEMA Premium® efficiency ratings and the fact that the mechanical features meet their requirements. One company reported that their energy consumption went down and their uptime increased by five to six percent.

Adoption of IEEE standards outside of the industries that wrote them is a sign of a good product.

XII. CONCLUSIONS

IEEE 841 has been widely accepted throughout various process industries as a simple way to specify and purchase a reliable energy-efficient severe duty motor off the shelf. Most suppliers make this product easily available from their inventory in various stocking centers. During the next standard revision cycle, IEEE 841 should be made more user-friendly and provide more consistency between suppliers as the specification was originally intended.

Overlap of IEEE 841 with the new API 547 standard should be considered during the revision cycle.

IEEE 841 motors would have wider acceptance outside of the petroleum and chemical industries if its name were changed from "IEEE Standard for Petroleum and Chemical Industry – To, "Severe Duty Premium Efficient (TEFC) Squirrel Cage Induction Motors."

The time has come for the Forest Products industry and other industries outside the Petroleum and Chemical industry to have their own standard for motors or broaden the name of IEEE 841 to gain more acceptances.

XIII. REFERENCES

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XIV. APPENDIX

Appendix A, a worksheet for showing the evolution of motor efficiency of IEEE 841 follows.

Appendix A. Evolution of Efficiency of IEEE 841 Motors

kW	HP	Voltage class	2-POLE			4-POLE			6-POLE			8-POLE		
			841 1994	841-2001	NEMA Premium®	841 1994	841-2001	NEMA Premium®	841 1994	841 2001	NEMA Premium®	841 1994	841 2001	NEMA Premium®
.75	1	600 V	75.5	77.0	77.0	82.5	84.0	85.5	80.0	81.5	82.5	74.0	75.5	-
1.1	1.5	600 V	82.5	84.0	84.0	84.0	85.5	86.5	85.5	86.5	87.5	77.0	78.5	-
1.5	2	600 V	84.0	85.5	85.5	84.0	85.5	86.5	86.5	87.5	88.5	82.5	84.0	-
2.2	3	600 V	85.5	86.5	86.5	87.5	88.5	89.5	87.5	88.5	89.5	84.0	85.5	-
3.7	5	600 V	87.5	88.5	88.5	87.5	88.5	89.5	87.5	88.5	89.5	85.5	86.5	-
5.5	7.5	600 V	88.5	89.5	89.5	89.5	90.2	91.7	89.5	90.2	91.0	85.5	86.5	-
7.5	10	600 V	89.5	90.2	90.2	89.5	90.2	91.7	89.5	90.2	91.0	88.5	89.5	-
11	15	600 V	90.2	91.0	91.0	91.0	91.7	92.4	90.2	91.0	91.7	88.5	89.5	-
15	20	600 V	90.2	91.0	91.0	91.0	91.7	93.0	90.2	91.0	91.7	89.5	90.2	-
19	25	600 V	91.0	91.7	91.7	92.4	93.0	93.6	91.7	92.4	93.0	89.5	90.2	-
22	30	600 V	91.0	91.7	91.7	92.4	93.0	93.6	91.7	92.4	93.0	91.0	91.7	-
30	40	600 V	91.7	92.4	92.4	93.0	93.6	94.1	93.0	93.6	94.1	91.0	91.7	-
37	50	600 V	92.4	93.0	93.0	93.0	93.6	94.5	93.0	93.6	94.1	91.7	92.4	-
45	60	600 V	93.0	93.6	93.6	93.6	94.1	95.0	93.6	94.1	94.5	91.7	92.4	-
55	75	600 V	93.0	93.6	93.6	94.1	94.5	95.4	93.6	94.1	94.5	93.0	93.6	-
75	100	600 V	93.6	94.1	94.1	94.5	95.0	95.4	94.1	94.5	95.0	93.0	93.6	-
95	125	600 V	94.5	95.0	95.0	94.5	95.0	95.4	94.1	94.5	95.0	93.6	94.1	-
110	150	600 V	94.5	95.0	95.0	95.0	95.4	95.8	95.0	95.4	95.8	93.6	94.1	-
150	200	600 V	95.0	95.4	95.4	95.0	95.4	96.2	95.0	95.4	95.8	94.1	94.5	-
190	250	600 V	95.4	95.4	95.8	95.0	95.0	96.2	95.0	95.0	95.8	94.5	94.5	-
		2300/ 4000V	95.0	95.0	94.5	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	-
220	300	600 V	95.4	95.4	95.8	95.4	95.4	96.2	95.0	95.0	95.8	-	-	-
		2300/ 4000V	95.0	95.0	94.5	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	-
260	350	600 V	95.4	95.4	95.8	95.4	95.4	96.2	95.0	95.0	95.8	-	-	-
		2300/ 4000V	95.0	95.0	94.5	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	-
300	400	600 V	95.4	95.4	95.8	95.4	95.4	96.2	-	-	95.8	-	-	-
		2300/ 4000V	95.0	95.0	94.5	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	-
340	450	600 V	95.4	95.4	95.8	95.4	95.4	96.2	-	-	95.8	-	-	-
		2300/ 4000V	95.0	95.0	94.5	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	-
370	500	600 V	95.4	95.4	95.8	95.4	95.4	96.2	-	-	95.8	-	-	-
		2300/ 4000V	95.0	95.0	94.5	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0	-

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